

AR Modeling as EEG Spectral Analysis on Prostration

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Abstract- Autoregressive (AR) modeling involves selection of an appropriate model order and the estimation of model parameters from the available data. Spectral estimation is then carried out using the model parameter. This spectral analysis is chosen as an alternative method to FFT in analysis of brain wave. Muslims prayer, termed as “*Salat*” in the Arabic language is a worshipping act which encompasses both physical movement of the body as well as silent *Quranic* recitation through mind and soul. The various positions in *Salat* include standing, prostrating, bowing and sitting. Prostrating is one of the unique position in *salat* which is believed can promote a relaxation effect to human body. In this study, AR was used to analyze the EEG signals during *salat* on prostrating position. The result shows that prostrating during *salat* generated higher alpha relative power (RP_{α}) as compare with mimic prostration. This finding concludes that prostration, one unique position in *salat* may promote a remarkable relaxation state to human mind and body.

I. INTRODUCTION

Brain is an electrochemical organ, functions as the portal for integrating and processing information and controlling center [1]. The activities of electrical potential inside the brain are recorded from the top scalp and displayed in the form of brain waves, usually known as electroencephalograph (EEG) [2]. Brainwaves are categorized into five basic groups which are delta (0.5-4 Hz), theta (4-8 Hz), alpha (8-13 Hz), beta (13-30 Hz) and gamma (>30Hz) [3, 4]. Each brain wave is believed to have its own frequency rhythm which is intensely correlated to the physical, emotional and spiritual state of the human body.

Alpha is one of the prominent brain wave in many brain behavior studies. This brain wave indicate relax or mental inactivity conditions and promoted by parasympathetic nervous system [1]. Stressful condition to human body and mind may causes from illness from light to chronic diseases. Diseases that may cause by stress are cardiovascular diseases [5], psychiatric disorder [6], and autoimmune diseases [7]. To prevent or reduce the effects of stress on the human body, an activity which can activate the parasympathetic nervous system hence generating the alpha wave signal from the brain is much needed.

Myriad numbers of study have been carried out to investigate the various relaxation methods and its effect to human brain. Meditation and prayer is one of the regular activity performed by religion's worshipper such as Muslims, Buddhists, Hindus and Christians. Some of their meditations or prayers have been proved to promote relaxing condition to human mind and body. Reference [8] performed a spectral analysis during Transcendental Meditation discovered that the frequency rhythm of both alpha and theta waves increased in a definite state during meditation. Reference [9], demonstrated that alpha and theta waves appeared during Zen Meditation. The Zen meditation subjects were familiar and mastered the voluntary breathing in their long experience. On the other hand, reference [10] investigated whether the physiological response correlates with a well-trained Kundalini Yoga Meditator. They found that alpha EEG activity enhanced during meditation when compared to the pre- and post-baselines.

Study on Muslims prayer has been conducted by reference [11] and their study found that the practice of Muslims prayer was capable of producing a state of calmness in the human mind. They also found that the Muslims prayer experienced higher gamma frequency after prayer. This finding was likely to be the result of an increase in concentration and thinking of the subjects.

Salat

Muslims prayer, termed as “*Salat*” in the Arabic language is a worshipping act which encompasses both physical movement of the body as well as silent *Quranic* recitation through mind and soul. There are basically four main positions involved in the prayer which are standing, bowing, prostrating and sitting. This Muslim prayer also involves the ‘*quranic*’ recitations and supplications (*du'a*) as well. These specific recitations and supplications must be verbalized when the worshipper assumes certain positions and performs movements between positions [11, 12].

In *Salat*, there is a unique posture; prostration which is believed can give significant reaction to the human body. Prostration is a posture where forehead, both hands and knees touching the floor.

In order to investigate the frequency rhythm during the meditation/prayer, spectral analysis is used. One common method that is being used is Fast Fourier Transform (FFT). However due to its weaknesses i.e. spectral leakage, other low resolution spectral analysis method is proposed. Autoregressive modeling is an alternative to the FFT to calculate the power spectral. This method provides smoother and more easily interpretable power spectrum than FFT. It is also a method of choice for high resolution spectral estimation of a short time series [13].

In this paper, AR is used to analyze the EEG signals during *salat* on prostrating and compare with the mimic prostration. *Dhuha* prayers, one of the additional prayers performed in the morning was chosen for this study. *Dhuha* prayer may be offered at any time starting approximately half an hour after sunrise until shortly before noon. It can be performed at a minimum number of two *rakaah* (cycles) in each prayer and a maximum number of eight cycles.

II. MATERIALS AND METHODS

A. Experimental Setup

Ten subjects between 20-29 years old were recruited in this study. None of them reported any neurological or psychiatric disorder. Each subject is required to answer a questionnaire to assess the prayer habits and their comprehension level of the prayer recitation.

EEG electrodes are applied to homologous frontal (F3, F4), central (C3, C4), parietal (P3, P4) and occipital (O1, O2) sites according to 10-20 International System. Electrode impedance was ensured to be below 5k Ω . The signals were sampled with a frequency of 250 Hz.

In the first session, subjects were asked to perform the *Dhuha* prayer for four *rakaah*. During prostration in the prayer, the subjects took approximately six to ten seconds and recited three repeated specific supplication. For the second session the subject was instructed to act out the *salat* position (stand, bow, sit, prostrate). The mimic sequence was repeated for four times and each position took fifteen seconds. Subjects were reminded to not close their eyes during prayer. The whole process of *salat* and mimic position was recorded. Then, the signal during prostrating was extracted and analyzed using MATLAB. The posture of prostration is shown in Fig. 1.



Figure 1. Posture of prostration during *salat*

B. Signal Processing

Autoregressive (AR) model

The AR model predicts the current value of a time series from the past value of the same series [13]. AR modeling of a time series is based on an assumption that the most recent data points contain more information than the other data point, and that each value of the series can be predicted as weighted sum of the previous values of the same series plus an error term. The AR model is defined by:

$$r_{xx}[k] = \frac{1}{N} \sum_{n=1}^{N-k} x[n]x[n+k] \quad (1)$$

where $x[n]$ is the current value of the time series, a_1, \dots, a_N are weighting coefficients, M is the model order, indicating the number of past values used to predict the current value, and $\varepsilon[n]$ represents a one-step prediction error, i.e. the different between the predicted value and the current value at this point.

AR modeling involves selection of an appropriate model order and the estimation of model parameters from the available data. Spectral estimation is then carried out using the model parameter [14].

A signal spectrum shows how the power (variance) is distributed as a function of frequency. AR spectral analysis can provide the number, centre frequency, and associated power of oscillatory components in a time series [13].

The power spectral density (PSD) can be estimated from variety of AR methods include autocorrelation, covariance, modified covariance and burg [15].

Burg's Method

The Burg's estimation method is based on minimizing the forward and backward prediction errors. The advantage of the Burg's method is it will resolve closely spaced sinusoids in signals with low noise levels. This method also estimates short data records, where PSD estimates are very close to the true values. One important advantage is this method ensures a stable AR model and is computationally efficient. Burg's method will be less accurate for high-order models, long data records and high signal to-noise ratios[16].

Data Analysis

The data was offline filtered with 2nd-order Band-pass Butterworth filter and 2nd-order Notch Butterworth filter. Then, 6th order autoregressive model using burg estimation was computed [17]. To avoid the artifact due to the physical movements, only fix positions were analyzed.

Alpha relative power (RP_{α}) representing the energy of the signal in the frequency range was calculated as below:

$$RP_{\alpha} = \frac{\int_{f_l}^{f_h} S_x(f)df}{\int_0^{f_{max}} S_x(f)df} \cdot 100$$

Where $f_{max} = 95$ Hz, $f_l = 8$ Hz, $f_h = 13$ Hz [18].

The non-parametric Wilcoxon signed-rank test was performed for statistical analysis.

III. RESULT & DISCUSSION

Through the AR modelling as described above the Alpha relative power (RP_{α}) was collected.

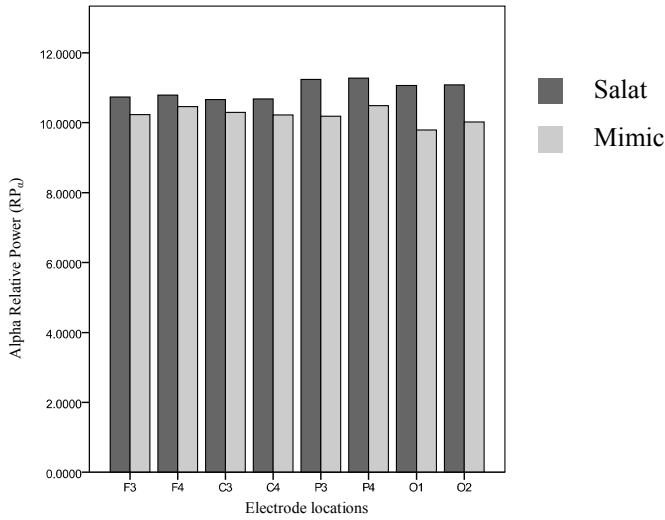


Figure 2. Relative power of alpha during *salat* and mimic prostration.

TABLE 1

Means and standard deviation (M ± S.D.) for the alpha relative power (RP_{α}) of the *salat* and mimic prostration.

Prostration	<i>p</i>	
	Solat	Mimic
Electrodes		
F3	10.74 ± 0.31*	10.23 ± 0.50
F4	10.79 ± 0.25*	10.46 ± 0.32
C3	10.67 ± 0.42*	10.30 ± 0.50
C4	10.68 ± 0.42*	10.23 ± 0.36
P3	11.24 ± 0.64*	10.19 ± 0.66
P4	11.28 ± 0.60*	10.50 ± 0.66
O1	11.07 ± 0.68*	9.80 ± 0.63
O2	11.08 ± 0.78*	10.02 ± 0.50

*Significantly different ($p < 0.01$) than the mimic prostration

Fig. 2 shows the mean of RP_{α} for all subjects during *salat* and mimic prostration. Table 1 demonstrates the means and standard deviations of RP_{α} for *salat* and mimic prostration and the significant difference. The results indicate that RP_{α} were significantly higher ($p < 0.05$)

during prostration in *salat* when compared with mimic prostration.

The results were significant for all electrode locations. This observation may indicate that the prostration posture affected the whole brain signal of the subjects. Therefore, the result was observed for all electrodes.

Results from the analysis were clarified as a desired signal and not an artifact. Major artifact of EEG, which is eye movement artifact or electroencephalograph (EOG), is laid in delta (0.5-4 Hz) and theta (4-8 Hz) [19]. This is out of range from the studied brain segment. The other main source of artifact is muscle or electromyography (EMG). This EMG signals were stronger and widely spread in range of 15 to 30 Hz [20, 21]. Again, this signal does not affect the desired signal.

IV. CONCLUSION

This paper describes the use of AR modelling as spectral analysis to the analysis of the EEG signals during *salat*. The results demonstrate that PSD generated from AR modelling can interpret the EEG signals effectively. This method can give accurate result for short term data, and make it easier for long term data. Therefore, this method can be applied to EEG practical application. The findings indicate that prostration during *salat* has remarkable effect to human brain as compared to mimic prostration. This alpha wave indicates relaxing condition in human body though activating of parasympathetic nervous system.

ACKNOWLEDGEMENT

The research was funded by The Prime Minister's Department as well as the University of Malaya's Postgraduate Research Grant (PPP). We sincerely acknowledge these contributions.

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